

A FLYING EJECTION SEAT

By R. H. Hollrock* and J. J. Barzda*

ABSTRACT

To increase aircrewmembers' chances for safe rescue in combat zones, the armed forces are investigating advanced escape and rescue concepts that will provide independent flight after ejection and thus reduce the risk of capture. One of the candidate concepts is discussed in this paper; namely, a stowable autogyro that serves as the crewman's seat during normal operations and automatically converts to a flight vehicle after ejection. Discussed are (1) the mechanism subsystems that the concept embodies to meet the weight and cockpit-packaging constraints and (2) tests that demonstrated the technical feasibility of the stowage, deployment, and flight operation of the rotor lift system.

INTRODUCTION

The United States Navy and Air Force envision an advanced aircrew-escape/rescue capability (AERCAB) that will provide independent flight after ejection, provide the crewman with a means of flight to areas better controlled by friendly forces, and permit rescue in safer, more accessible sites than is often the case at present. Thus, an aircrewman's chances for safe rescue will be increased, particularly in combat zones. The concept is proposed initially for fighter/attack aircraft.

Primary performance goals for AERCAB are shown in figure 1. The cruise altitude is just above the range of small-arms fire. The AERCAB design objectives also specify that (1) current escape capabilities/envelopes will not be compromised, (2) deployment and conversion will be fully automatic, (3) the system must be capable of operation in adverse weather, and (4) retrofit into A-7 and F-4 aircraft is highly desirable.

Four proposed concepts are being demonstrated and evaluated for eventual selection as the operational system. One concept is a parawing system propelled by a turbofan engine installed on the back of the ejection seat. Fuel cells are located on both sides of the seat. The parawing is deployed and flown with the crewman in a face-down position. In the second concept, a "Princeton sailing," a deployable fixed wing, is used to provide lift. The craft contains a turbofan engine and a telescoping tail boom.

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Fuel is stored in bladders inside the hollow leading-edge wing spars. The wings and tail surfaces are deployed by parachute at or near flight velocities. These two concepts are depicted in figure 2. In a third concept, a rigid, deployable metal wing is used. Submitted after other concepts had begun to be tested, the rigid wing is still in early development. The fourth candidate concept is the Stowable Aircrew Vehicle Escape ROTOSEAT (SAVER), the primary subject of this paper. ROTOSEAT and SAVER are registered for exclusive use by Kaman Aerospace Corporation.

SAVER AERCAB

System Description

The SAVER is a compact autogyro that folds and stows into the aircraft cockpit to serve as the crewman's seat during normal operations. In an emergency, the SAVER ejects with the crewman and converts to the flight-vehicle configuration. The configurations are depicted in figure 3, showing the full-scale wind-tunnel model. At the end of the flight, the crewman is separated from the SAVER and parachutes to the ground. All events from ejection through conversion and autogyro flight to the final parachute descent are automatic. The crewman only needs to pull the ejection-initiation control. In flight, he may override the automatic flight control and programmed events if he desires. The SAVER includes an alternate parachute mode of escape for low altitudes and speeds, retaining current escape envelopes. The parachute-mode functions are also performed automatically. The applicable escape mode is determined and initiated by means of an onboard selector. The SAVER is designed for retrofit in the A-7 and F-4 aircraft; it fits between the cockpit control consoles and mounts on the existing seat-mounting bulkheads. The major structure of the aircraft is unaffected.

The SAVER provides 30 minutes of flight at a velocity of 51.4 m/sec at an altitude of 914 meters, just above the range of small-arms fire. The service ceiling is approximately 3000 meters. The maximum rate of climb is almost 5 m/sec. Propulsive power is provided by a small turbofan engine with a sea-level thrust rating of 1280 newtons.

Deployment and Operation

The deployment/conversion sequences from ejection through rotor deployment into autogyro flight are shown in figure 4. The crewman pulls the face curtain or control to initiate ejection. Events are subsequently automatic. Current ejection-seat techniques, escape dynamics and velocities, and programming are applied in the ejection phase. After ejection, when the aircraft structure has been cleared safely, the extraction drogue parachute pulls the stowed blades aft and upwards to the trail position, rotates the seat into deployment alignment, and serves as the initial drogue parachute and stabilizer. Rotor-hub- and blade-tip-restraint bolts are then severed with squib cutters, and the deployment springs position the hub and blades into position for spinup. Aerodynamic torque about the shaft axis spins up the rotor assembly, and centrifugal force extends the telescoped blades to full span. The drogue parachute is jettisoned after full spinup. Conversion to the autogyro mode is initiated after deceleration to

near flight velocity. The rotor, engine, and tail surfaces are actuated to flight positions. The SAVER then makes a transition into powered autogyro flight after inflight startup of the engine and automatic flight-control guidance.

Design

A major criterion in the preliminary design of the SAVER was that the folded vehicle fit into a fighter cockpit. In effect, the SAVER was designed in reverse order; that is, the packaged outline having been determined, unique mechanisms that folded and fitted within the envelope had to be devised and embodied into the SAVER to achieve the specified packaging, deployment, control, and flight goals. The system also is designed to rescue dazed, injured, and nonpilot crewmen in fair or adverse weather conditions. Rearward vision in the parent aircraft was to be minimally compromised.

The most unique subsystem mechanism is the rotor installation. When stowed, the installation forms a compact package 1.22 meters long and 0.2 meter wide and fits at the rear of the seat. When deployed, it forms a rotor 4.27 meters in diameter. To convert from a stowed package to a spinning rotor, special features that had to be included were the following.

1. Two-panel telescoping blades with integral blade-extension stops
2. A stretchable, energy-absorbing cable to control the stop-impact loads during blade extension
3. Double-hinged blade retention for spinning up the rotor, governing the speed of rotation, and folding the blade
4. A rotor spinup mechanism that, when severed by pyrotechnic cutters, set the hub-geometry for aerodynamic spinup of the rotor
5. A drogue parachute to extract and orient the rotor package through rotor spinup, with a provision for jettisoning the parachute when the rotor attained operational speeds of rotation

The rotor-control system serves dual purposes. During the rotor-deployment phase, the system properly orients the rotor from behind the seat to the trailing decelerator position. After conversion to the autogyro mode, the control system becomes a direct rotor-tilt-control system, providing longitudinal and lateral tilt. The system may be operated both by the crewman and by an automatic flight-control system.

The automatic flight-control/navigation system positions the SAVER at flight altitude and flies it to a predetermined area without crewman input (in the event the crewman is injured or dazed or is a nonpilot). The system is programmed with the direction for return flight, and it heads and guides the vehicle in this direction; flies the SAVER upright in a safe, stable manner; and monitors terrain clearance. Control techniques and logic used in current autopilots, remotely piloted vehicles, droned helicopters, and unmanned spacecraft are utilized. The crewman may override automatic flight with a sidearm-formation stick if he so wishes.

Total-system compactness was achieved by integrating components and assigning dual functions where possible. The fins are stowed alongside the seat, take on the outline pattern of the seat panel, and are mounted on hinged booms, which also serve as the catapult/boost-rocket cases. Ejection guide rollers also are mounted on the boom tubes. A small horizontal stabilizer is mounted between the booms near the fins. The empennage is deployed into flight position by a pyrotechnic actuator.

The engine deployment is coupled with that of the tail. The propulsion engine, a small turbofan, is stowed behind the seat between the headrest and folded rotor. The turbofan design is based on current engine technology; for example, existing small gas turbines operating at SAVER-engine thrust-to-weight ratios, length-to-diameter ratios, and specific fuel consumptions. Inflight cartridge-impingement startup is planned.

The SAVER also includes a life-support system (in case of high-altitude ejection), survival gear, and a personnel-recovery parachute. The parachute, stowed in the headrest, is spread ballistically for fast action at low altitudes and speeds.

At the end of flight, the crewman is separated from the seat with a conventional lumbar inflatable bladder and descends with the parachute. To preclude subsequent flight into the descending crewman, the rotor blades are jettisoned with linear shaped charges near the root-end retention. Centrifugal force slings the blades clear of the crewman.

All functions throughout the ejection, rotor-deployment, conversion, and flight phases are programmed, timed, and initiated by a mode-selector/events programmer. A precision electroballistic sequencing and initiating system provides the control intelligence. If a malfunction occurs, sequencing diverts to the parachute mode of escape.

Testing

Wind-tunnel and autogyro-mode flight tests with full-scale hardware have been performed to demonstrate technical feasibility. The wind-tunnel demonstrations were performed in September 1970 in the NASA Ames Research Center 12.2-by-24.4-meter facility with a full-scale SAVER preliminary-design-configuration model. The model was folded into the seat configuration and was designed to demonstrate the deployment/transition events. Successfully demonstrated in the tests were decelerator-mode rotor operation at speeds up to 93 m/sec; rotor extraction, spinup, and operation in seat wake at 82.5 m/sec; conversion from decelerator-mode to flight-mode configuration; and autogyro-mode operation at speeds up to 56 m/sec. Demonstration tests are shown in figure 5.

The model was then adapted to a powered, manned flight-test vehicle in the ground-takeoff/landing autogyro mode by the addition of landing gear, a propulsion system, manual flight control, and instrumentation. The autogyro-mode manned flights (fig. 6), completed in January 1972, were the first flight of a turbofan-powered autogyro and the first manned flight of a telescoping-blade rotor. Demonstrated in these flights were manned flight of the SAVER rotor, stable and controllable rotor and vehicle behavior, rotor lift capability 14 percent above design normality, flight of a trainer prototype, and adaptability of turbojet power to autogyro propulsion.

CONCLUDING REMARKS

Aircrew-escape/rescue capability is being planned to increase the chances for the safe rescue of aircrewmembers by providing features that will reduce the risk of capture, facilitate location and rendezvous, reduce on-the-ground exposure time, and permit rescue in safer, more accessible areas.

The Stowable Aircrew Vehicle Escape ROTOSEAT autogyro aircrew-escape/rescue-capability candidate system meets the cockpit-stowage, aircraft-retrofit, and flight-performance requirements. Experimental demonstration tests have thus far indicated that this system is a viable and technically feasible approach. Inflight deployment, the planned next phase, will complete the military requirement for feasibility demonstration and evaluation.

DISCUSSION

J. E. Price:

What is the minimum altitude at which the system will operate?

Barzda:

The SAVER is designed to convert to and operate in the AERCAB "flying ejection seat" mode when the ejection altitude is 1000 feet or more above the terrain. The "parachute mode" recovery will be initiated for ejections below the 1000-foot minimum altitude. The normal cruise altitude for the AERCAB is 3000 feet.

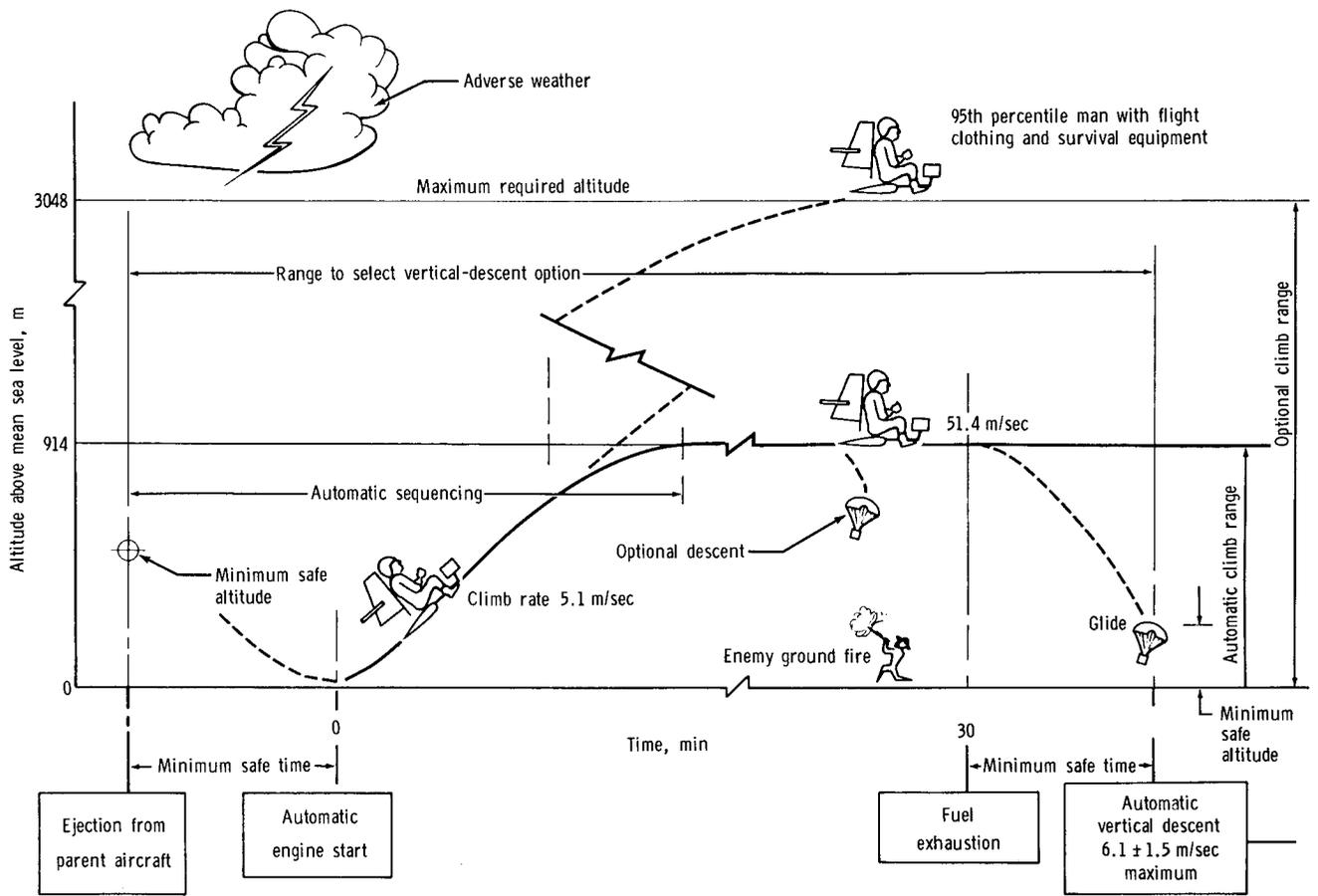


Figure 1. - Performance goals for AERCAB.

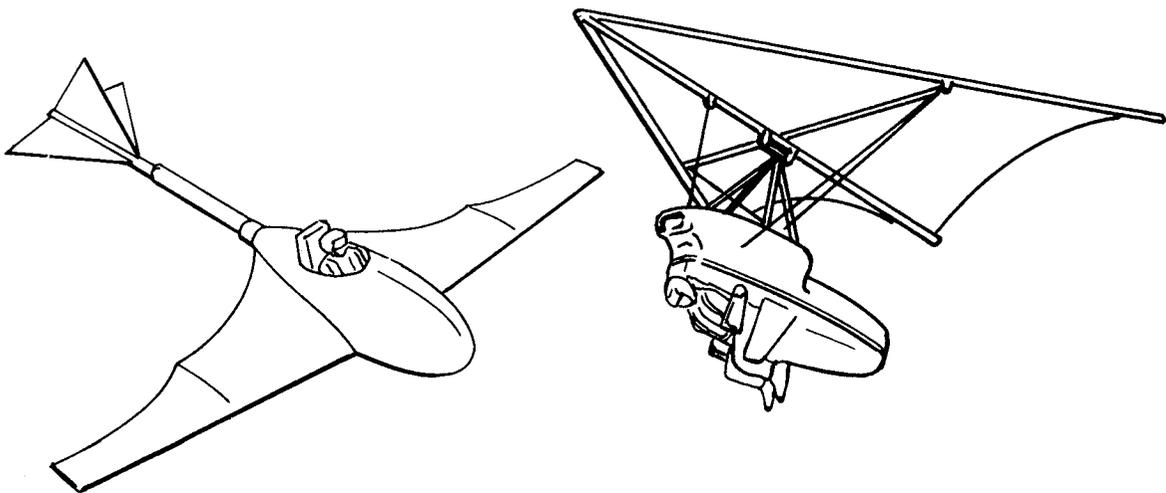
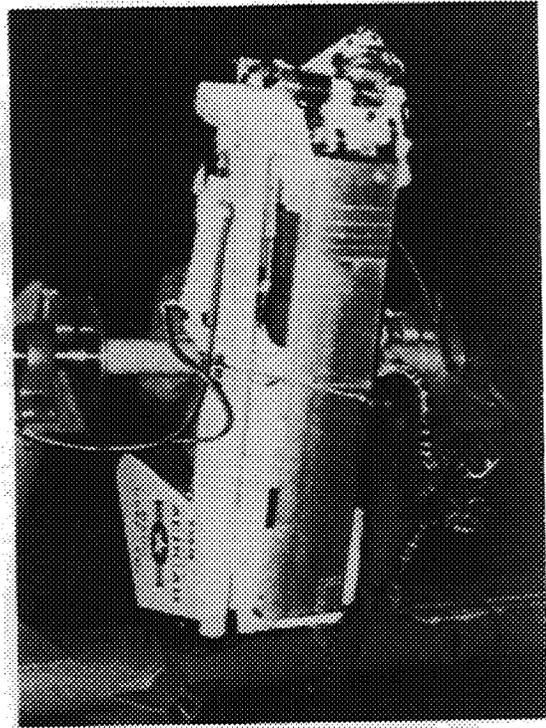


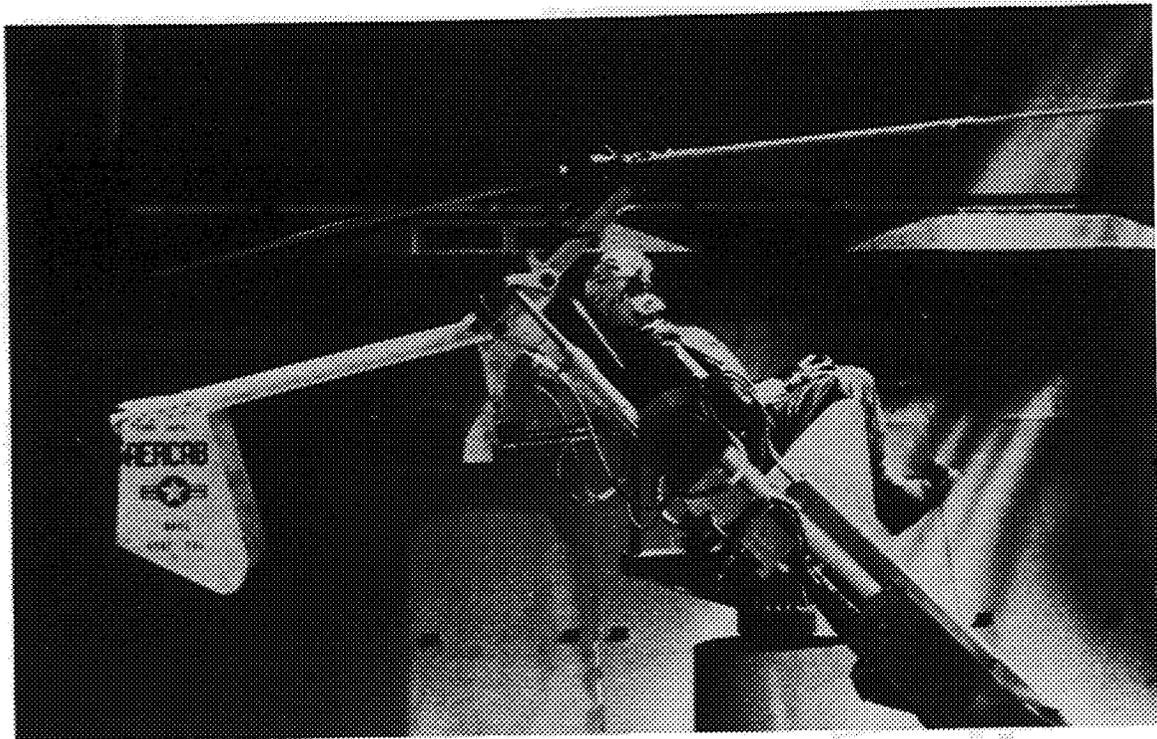
Figure 2. - Winged AERCAB concepts.



(a) Stowed-ejection-seat mode, front.

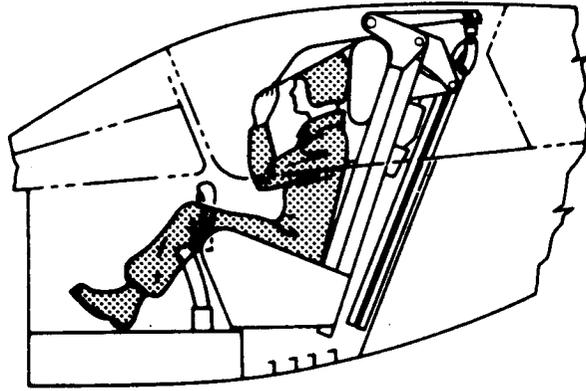


(b) Stowed-ejection-seat mode, rear.

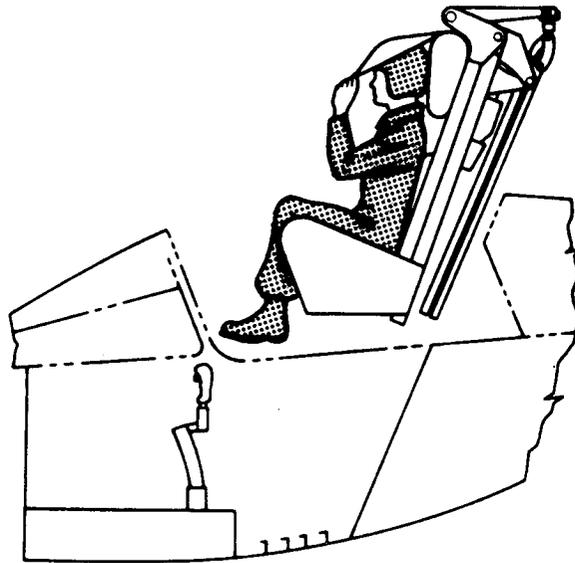


(c) Deployed-autogyro-flight mode.

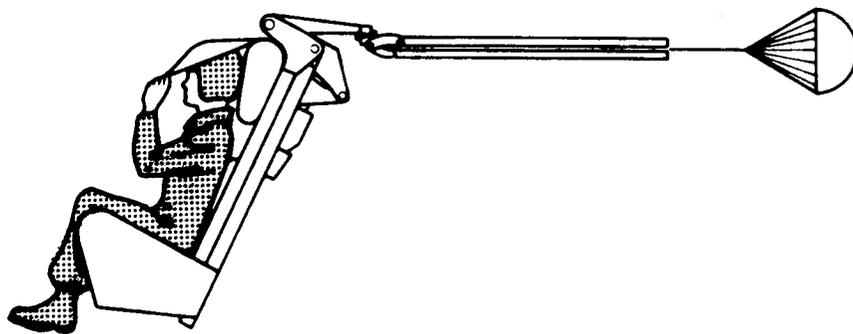
Figure 3. - The SAVER AERCAB.



(a) Initiation.

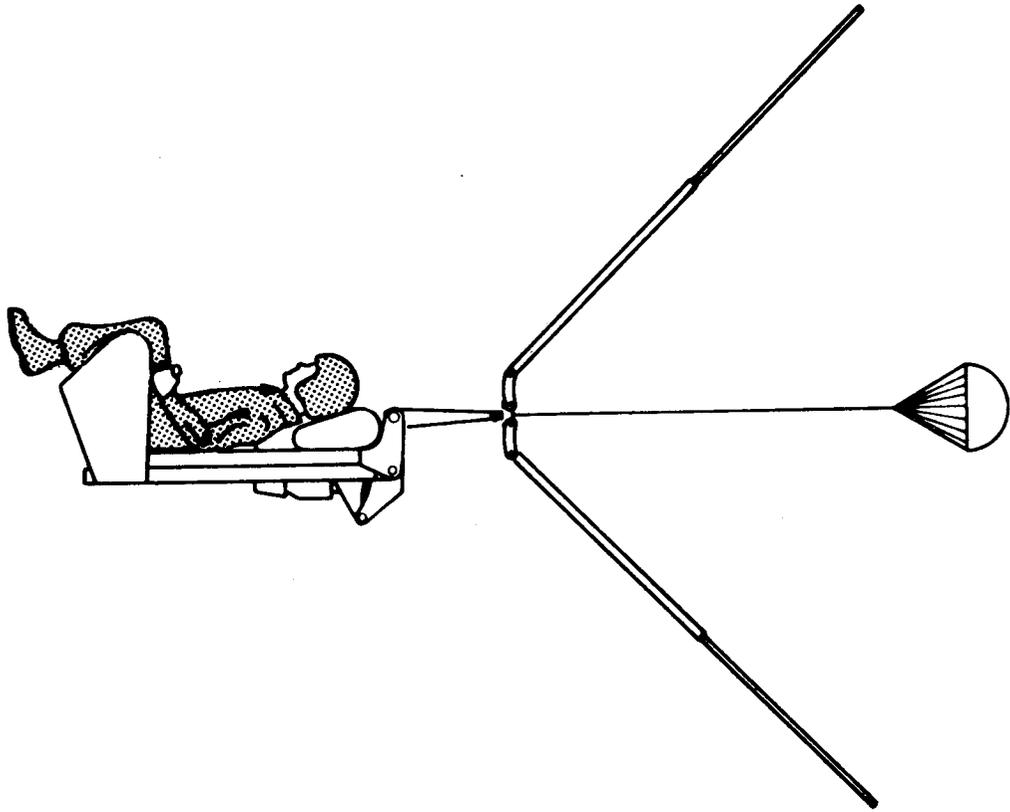


(b) Ejection.

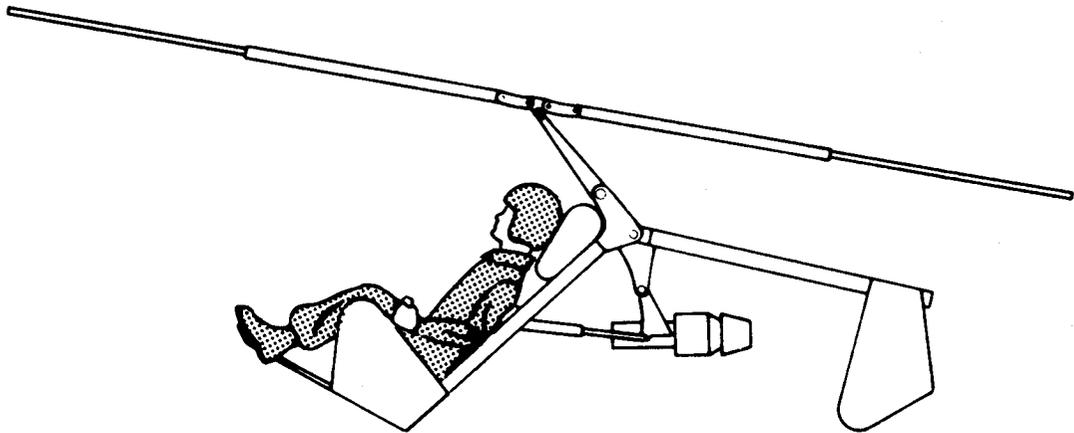


(c) Drogue-parachute deployment.

Figure 4. - The SAVER deployment sequence.

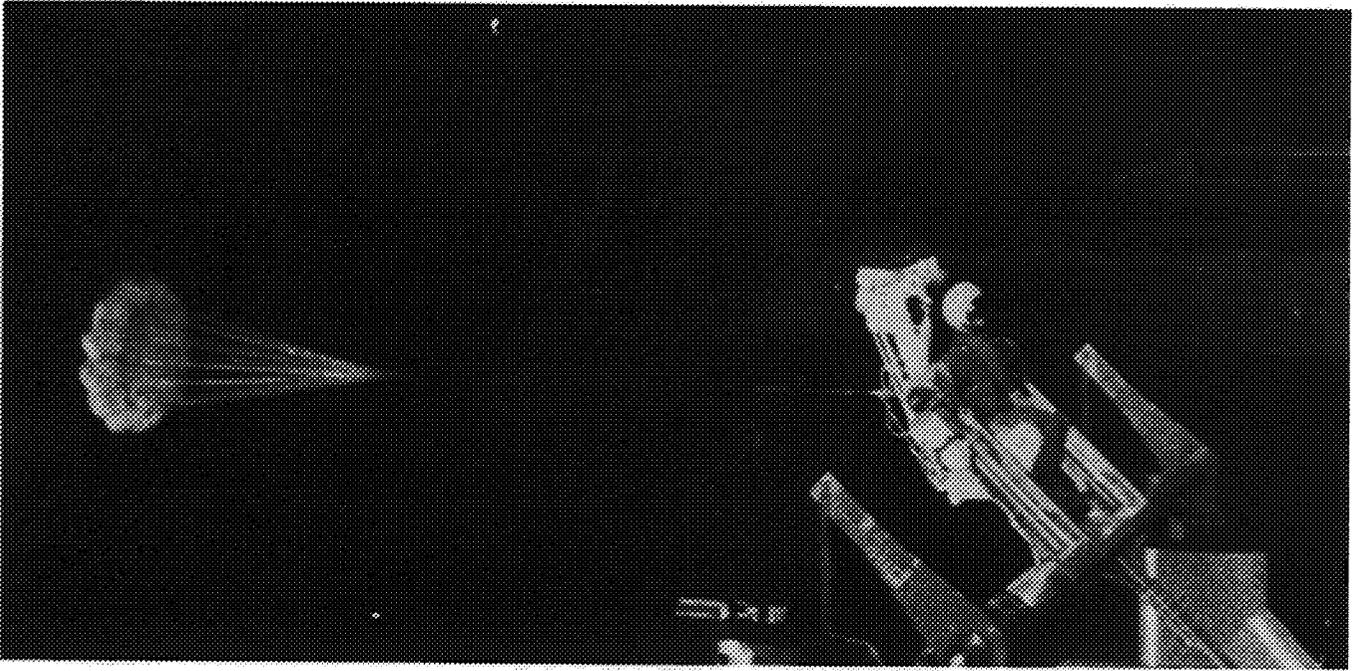


(d) Rotor deployment.

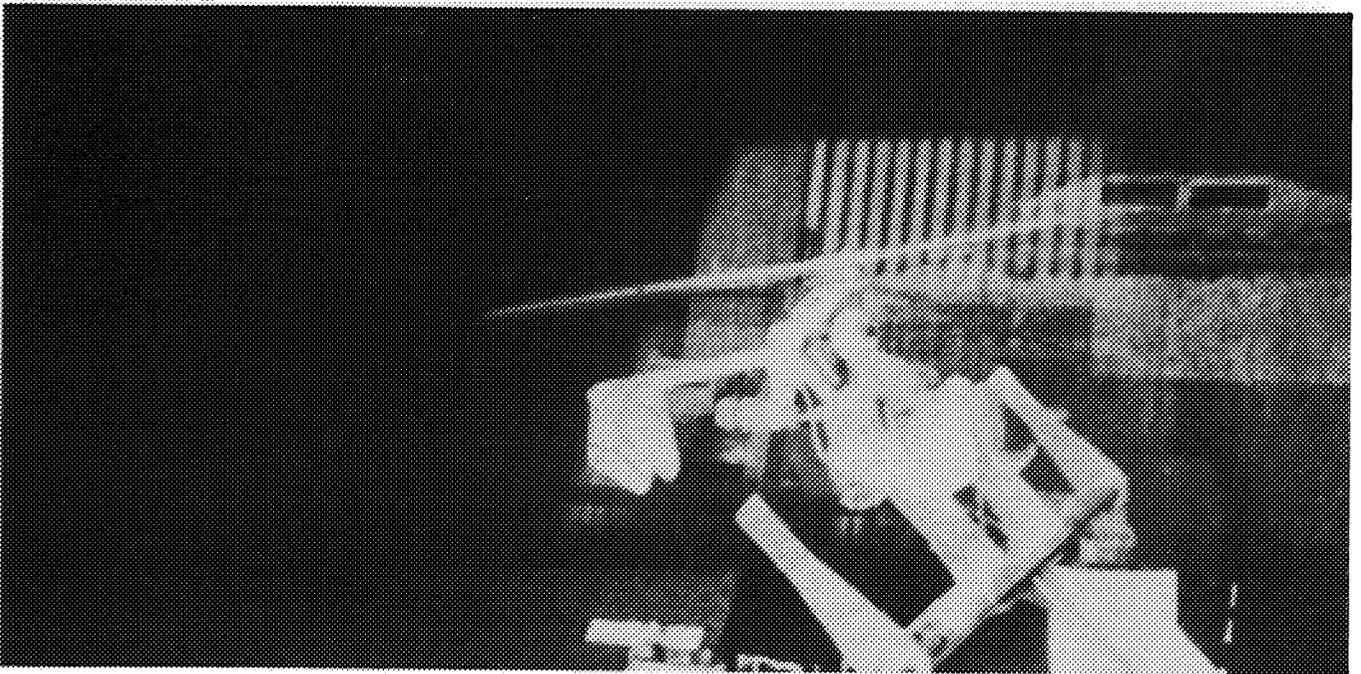


(e) Autogyro mode.

Figure 4. - Concluded.

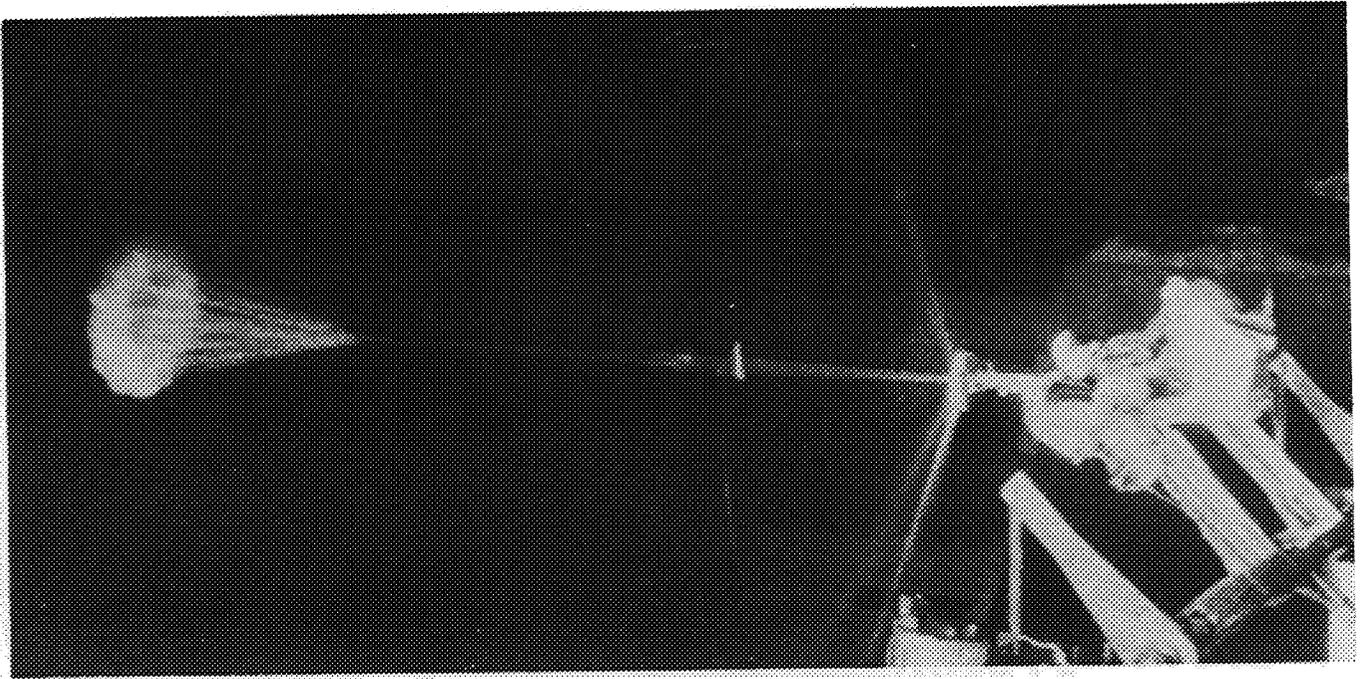


(a) Drogue-parachute deployment (82.5 m/sec).

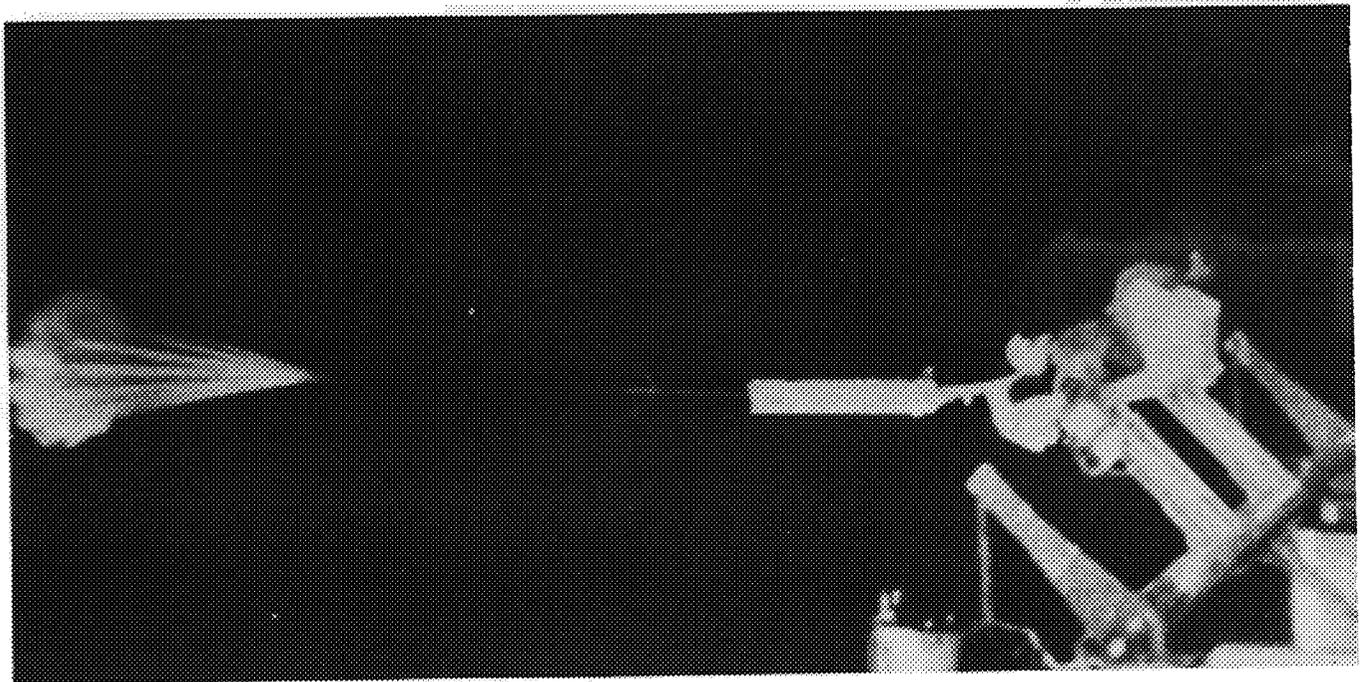


(b) Rotor extraction (82.5 m/sec).

Figure 5. - Full-scale-prototype feasibility demonstration of the SAVER.



(c) Rotor spinup (82.5 m/sec).



(d) Autogyro mode (56 m/sec).

Figure 5. - Concluded.

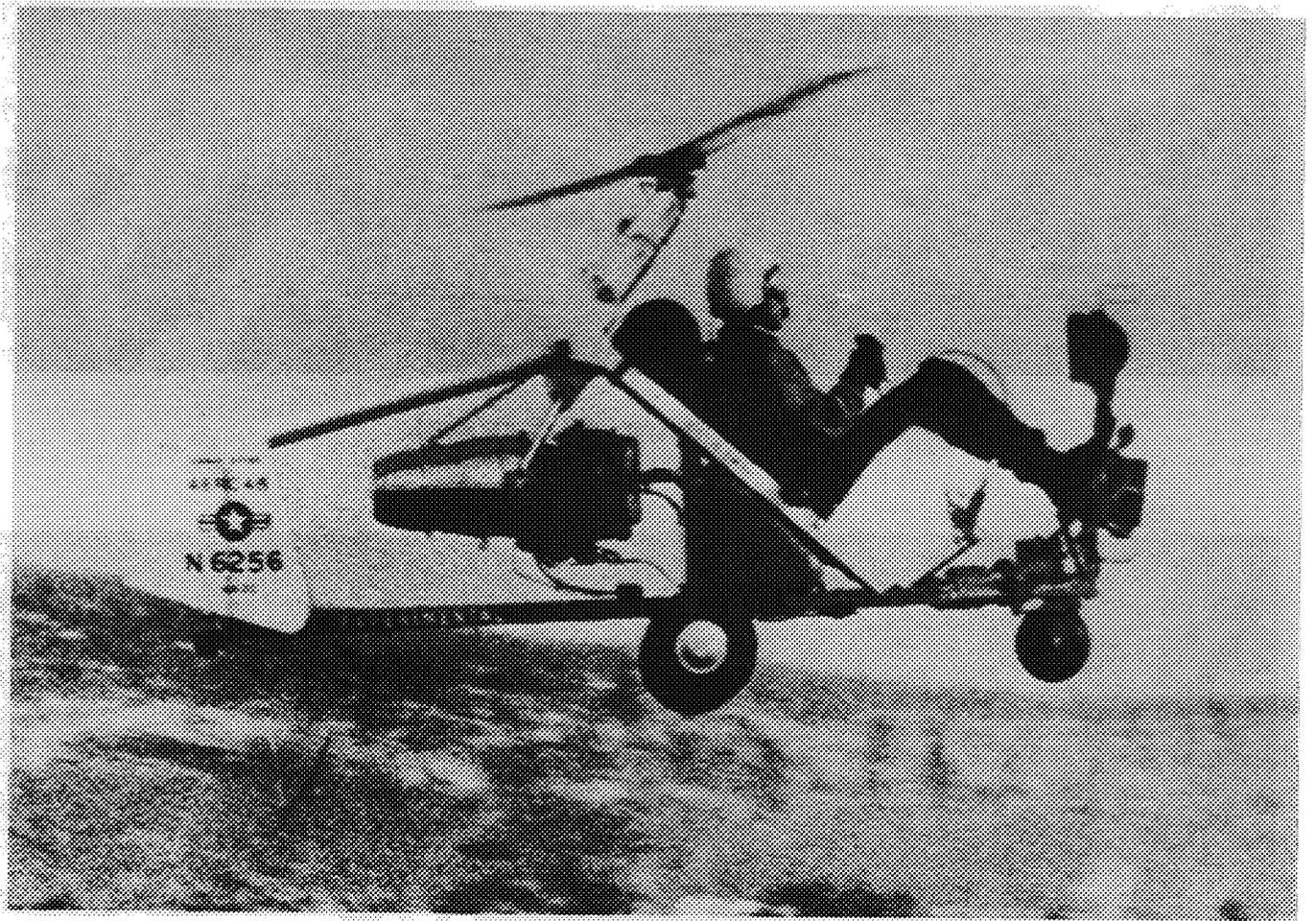


Figure 6. - Autogyro-mode manned flight of the SAVER.